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Toxic Beauty: Evaluating the Toxicological Risks of Heavy Metals in Facial Cosmetics and Implications for Public Health in Calabar, Nigeria

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ABSTRACT

Facial cosmetics beautify, but combined usage may expose users to harmful heavy metals. This study evaluates that toxic risk. A survey involving 300 female participants was conducted to identify the most commonly used cosmetic brands—Brands A, B, C, and D. A total of 576 cosmetic samples, including foundations, face powders, lipsticks, and eye pencils, were purchased bimonthly over six months. Samples were prepared through acid digestion and analyzed for metal content using atomic absorption spectrophotometry. Health risk assessment was conducted using systemic exposure dosage (SED), margin of safety (MoS), hazard quotient (HQ), hazard index (HI), and lifetime cancer risk (LCR) models. Metals concentrations (mg/kg) across all brands were in the following ranges: lead (0.066-0.789), cadmium (0.093-0.787), chromium (0.049-0.543), cobalt (0.048-0.902), nickel (0.033-0.704), and iron (0.021-0.641). Metal concentrations varied significantly across brands and product types (ANOVA, $p \leq 0.05$). Nickel and cadmium levels in most products exceeded WHO and Health Canada limits. The SED values revealed that Co, Cd, and Pb posed the highest risks, particularly in Brand A and Brand C products. MoS calculations indicated that Cd and Co posed significant safety concerns. HQ values confirmed that Cd and Co exceeded the non-carcinogenic risk threshold. The HI values were above unity, suggesting cumulative health risks. LCR values for Cd, Ni, and Cr were above the acceptable risk range, indicating potential cancer risks. The study concludes that prolonged use of studied cosmetics poses both carcinogenic and non-carcinogenic risks. Routine screening of cosmetic products to ensure compliance with safety standards is strongly recommended.

Keywords*:* Facial cosmetics, Metals exposure, Safety Standards, Carcinogenic Risk, Non-Carcinogenic Risk, Regulatory Compliance.

Introduction

The term "toxic beauty" encapsulates the paradox of using cosmetics for beautification while simultaneously exposing oneself to harmful substances. It highlights the irony of achieving aesthetic appeal at the expense of health, especially when long-term exposure to contaminants like heavy metals results in serious medical conditions.[1] This term has gained traction in raising awareness about the hidden dangers lurking in everyday beauty products. Cosmetics are products formulated for cleansing, beautifying, and enhancing the appearance of the human body. They have been a staple of human culture for centuries, with their usage dating back to ancient civilizations such as Egypt, Greece, and Rome.[2]

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Modern cosmetics encompass a wide range of products, including skincare, haircare, and facial cosmetics such as face powders, foundations, lipsticks, and eye pencils. The primary purpose of cosmetics is to enhance appearance, promote confidence, and reflect cultural or personal identity.[3] Facial cosmetics, specifically, are designed to provide coverage, highlight features, and create a desired aesthetic effect. For example, foundations and powders create an even skin tone, while lipsticks and eye pencils add colour and definition to facial features. Beyond aesthetic benefits, many modern cosmetics incorporate skincare elements such as moisturizers, sunscreens, and anti-aging properties.[4] These products are widely favoured for their convenience and ability to cater to individual beauty needs, making them indispensable in modern society. Additionally, the incorporation of moisturizing agents and vitamins in some cosmetics adds functional benefits, such as skin hydration and nourishment.[5] Heavy metals in cosmetics can originate from both intentional and unintentional sources. Intentional incorporation occurs when metals are used as pigments, colorants, or stabilizers to enhance product appearance and longevity. For example, lead compounds are often used in lipsticks for their vibrant hue, while chromium oxide greens are common in eye pencils.[6] Unintentional contamination arises during manufacturing processes, where raw materials may contain trace amounts of metals. These include arsenic, cadmium, and mercury, often introduced through mineral-based ingredients or during improper production and packaging.[7] Additionally, environmental factors such as contaminated water and air used during manufacturing can exacerbate metal presence in these products.[8]

Heavy metals in cosmetics pose significant health risks due to their potential to accumulate in the body over time. These metals can enter the body through incidental ingestion, dermal absorption, or contact with mucous membranes. For instance, lipsticks are easily ingested during application or eating, while foundations and powders can be absorbed through the skin.[9] Once inside the body, heavy metals such as lead, cadmium, and mercury exhibit toxicological effects. Lead exposure is associated with neurotoxicity, developmental delays, and reproductive health issues. Cadmium can induce renal dysfunction and bone demineralization, while mercury exposure may lead to neurological and immune system disorders.[10] Chronic exposure to these metals through daily use of contaminated cosmetics undersc-ores their public health implications. Nickel (Ni) and lead (Pb) exposure through cosmetics can lead to severe dermatitis and renal failure, respectively.[11] Chromium (Cr), especially in its hexavalent form, is a significant environmental pollutant known for its carcinogenic and allergenic effects in humans.[12] Cobalt, commonly found in lipsticks, eyes shadows, face paints, hair creams, shampoos, relaxers, and conditioners, is frequently used as a colouring agent in cosmetics and light-brown hair dyes. However, it is a known skin allergen responsible for allergic contact dermatitis.[12] Mercury compounds, readily absorbed through the skin, can accumulate in the body, leading to allergic reactions, skin irritation, or neurotoxic effects.[11] Numerous reports of mercury intoxication from cosmetics have emerged in recent years, with evidence indicating that in-utero exposure can cause developmental issues, including motor difficulties, sensory problems, and cognitive impairments in children.[11] Copper, an essential trace element in the human body, is also widely used in cosmetics as a colouring pigment or to block UV rays. Regulatory guidelines specify a permissible limit of 50 μg/g for copper when used as a cosmetic colour additive.[12]

Research has quantified the amount of heavy metals absorbed through cosmetic usage. Studies estimate that users ingest between 0.1 and 0.3 grams of lipstick per day, resulting in daily lead exposure of up to 10 micrograms.[13] Dermal absorption studies suggest that up to 1% of applied lead in face powders and foundations may penetrate the skin barrier.[14] Similarly, soft tissue exposure from eye pencil usage has been shown to contribute to elevated cadmium levels in ocular tissues.[15] Gao *et al*.,[16] estimated that lipsticks may contribute up to 0.2 mg of lead per day for regular users, while foundations and powders can lead to the absorption of trace metals through prolonged skin contact. Dermal absorption rates depend on factors such as the metal's molecular weight, skin condition, and the presence of enhancing agents in the cosmetic formula.[17] Patel,[18] estimated that a woman ingests approximately four pounds of lipstick in her lifetime.

Existing studies have predominantly focused on heavy metal contamination in isolated cosmetic products or specific regions, leaving gaps in comprehensive, localized assessments. For example, there is limited data on the cumulative exposure from combined use of multiple products in the Nigerian context.[3] Furthermore, while the toxicological impacts of individual heavy metals are well-documented, synergistic effects of multiple metal exposures remain underexplored. [15] This research aims to address these gaps. It is novel in providing a detailed quantification of heavy metal concentrations in popular facial cosmetics available in Calabar, Nigeria, and in evaluating the public health implications due to cumulative exposure from combined use of multiple products such as powders, foundations, lipsticks, and eye pencils. By identifying contamination levels and their toxicological risks, this study contributes to regulatory policy formulation and public health awareness. By integrating consumer-based brand selection, temporal sampling, and precise metal quantification using AAS, the study applies a comprehensive risk assessment framework—including SED, MoS, HQ, HI, and LCR—to translate metal concentrations into meaningful public health insights. The methods are robust, context-specific, and regulatory-relevant, making the findings both scientifically credible and vital for cosmetic safety policy in developing settings.

Materials and Methods

Design and Administration

To assess consumer preferences and usage patterns of facial cosmetic products, a structured questionnaire was developed and administered to 300 female participants aged 18 years and above. Participants were randomly selected from four major commercial hubs in Calabar (8 Miles, Marian, Watt, and Mbukpa Markets), as well as two the major tertiary institutions in Calabar (the University of Calabar and the University of Cross River State, Calabar Campus). The questionnaire, adapted from the validated framework of Iwegbue *et al*.[19], was designed to capture data on the most frequently used brands of foundation, face powder, lipstick, and eye pencil. Informed consent was secured from all respondents. The data served as a basis for identifying the most widely consumed cosmetic products for subsequent heavy metal content analysis.

Sample Collection

The sample collection procedure was adapted from Udofia *et al*.,[20] Three units of each of the cosmetics products (foundation, powder, lipstick and eye pencil) belonging to identified brands were purchased every two months from the four major markets in Calabar. All samples collected on the same day were confirmed to belong to the same production batch. This sampling process was repeated three times over six months, resulting in 192 samples (48 foundations, 48 powders, 48 lipstick, and 48 eye pencil) being collected per session, for a total of 576 samples. Samples were transported to the Biochemistry Laboratory of the University of Calabar for preparation and analysis.

Sample Preparation and Analysis

Three units of each product from a specific market were combined into a composite sample. A 20 g portion of the composite sample was digested using a mixture of concentrated nitric and hydrochloric acids in a 3:1 ratio on a hot plate. The digested sample was filtered through Whatman No. 1 filter paper into a 50 mL volumetric flask and diluted with distilled water to reach the desired volume. The concentrations of lead (Pb), cadmium (Cd), chromium (Cr), cobalt (Co), nickel (Ni), and iron (Fe) in the prepared samples were measured using Shimadzu Atomic Absorption Spectrophotometer (model AA-6800, Japan)

Health Risk Assessment

The potential health risks associated with exposure to Pb, Cd, Cr, Co, Ni, and Fe in the analyzed cosmetic products were evaluated using the US-EPA,[21] model. Systemic exposure dosage (SED), margin of safety (MoS), hazard quotient (HQ), hazard index (HI), and lifetime cancer risk (LCR) were calculated to assess the potential risks.

Systemic Exposure Dosage (SED)

The SED, which estimates the amount of metal absorbed through cosmetic use, was calculated using Equation 1:

$$\text{SED (mg/kg/d)} = \frac{\text{Cs} \times \text{AA} \times \text{SSA} \times \text{F} \times \text{RF} \times \text{BF} \times 10{-}3}{\text{BW}} \ldots (1)$$

Where:
Cs indicates metal concentration in the sample (mg/kg);
SSA is the surface area of skin onto which the product is applied (cm^2);
AA shows the quantity applied (g/cm^2);
RF is the retention factor; F indicates the application frequency of a product per day;
BF is the bio-accessibility factor, 10^{-3} (mg/kg) is used as the unit conversion factor;
BW is the average body weight (70 kg).

The lowest no observed adverse effect level (NOAEL) value was calculated using equation 2

$$\text{NOAL} = RfD \ x \ UF \ x \ MF \ \ldots (2)$$

Where:

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UF is an uncertainty factor (reflects overall confidence in the various data sets).
MF is a modifying factor (based on the scientific judgment).
RfDs represent dermal reference doses (mg $kg^{-1}d^{-1}$) of different metals.

The default values for MF and UF are 1 and 100 respectively. The dermal reference doses for Cd, Cr, Fe, Ni, and Pb are 0.005, 0.015,140, 5.4, and 0.42 mg/kg/d. [21, 22]

Margin of Safety (MoS)

The margin of safety was determined as the ratio of the lowest observed adverse effect level (NOAEL) to the SED, as outlined in Equation 3:

$$MoS = \frac{NOAEL}{SED} \ldots (3)$$

Hazard Quotient (HQ) and Hazard Index (HI)
The hazard quotient (HQ) is the ratio of systemic exposure dosage (SED) of a substance to the dermal reference dose (RfD) of each metal. $HQ \geq 1$ indicates a potential health risk, whereas an $HQ < 1$ suggests that the risk is negligible or not significant.[21, 23] The HQ was calculated using equation 4.

$$HQ = \frac{SED}{RfD} \ldots (4)$$

The summation of hazard quotients for all the heavy metals is the hazard index (HI). It is computed to evaluate human health risk due to the exposure of all metallic impurities. The HI value was calculated following El-Aziz *et al.*,[24] equation 5

$$HI = \sum HQ = HQ_{Pb} + HQ_{Cd} + HQ_{Cr} + HQ_{Co} + HQ_{Ni} + HQ_{Fe} \ldots (5)$$

Lifetime Cancer Risk (LCR)
The lifetime cancer risk is usually investigated for carcinogenic metals. In this study, LCR was determined following El-Aziz *et al.*,[24] equation 6

$$LLCR = SED \times SF \ldots (6).$$

Where SF represents the carcinogenicity slope factor $(mg/kg/d)^{-1}$. The reported slope factor for Pb, Cr, Ni, and Cd are 0.0085, 0.5, 0.91, and 6.7 $(mg/kg/d)^{-1}$ respectively. [24, 25]

Statistical Analysis
Analysis of variance (ANOVA) was used to determine significant differences in metal concentrations across product brands and sampling periods. Results were considered significant at p<0.05p < 0.05p<0.05. Depending on homogeneity of variances, either Duncan's multiple range test or Dunnett's T3 test was used for multiple comparisons. Statistical analysis was carried out using IBM SPSS version 23 for windows

Analytical Quality Assurance
The study maintained a high standard of quality control to ensure dependable results. Samples were carefully managed to minimize any chance of contamination. All glassware was thoroughly cleaned, and only deionized distilled water was utilized in the procedures. High-purity reagents, including HNO_3 (Riedel-deHaen, Germany) and HCl (British Drug House Chemicals Limited, England), were chosen for their analytical-grade quality. Blank samples and mixed standards were included in each analytical batch to monitor background levels and maintain uniformity. The reliability of the findings was further validated through the use of Standard Reference Materials (IAEA-336 Lichens), processed using the same digestion and analysis methods, and compared to certified target values.

Results and Discussion

Consumer Usage Patterns from Questionnaire Survey
Of the 300 distributed questionnaires, 257 were properly completed, revealing that 66.6% of respondents, primarily within the 18–45 age group, preferred four specific cosmetic brands, coded as Brand A, B, C, and D. These brands emerged as the most frequently used across all sampled locations and were consequently prioritized for laboratory analysis due to their high usage rates and potential for widespread exposure.

Quality Assurance
The analysis of the Standard Reference Material (Lichen IAEA-336), subjected to identical preparation and testing procedures as the cosmetics samples, produced results consistent with the certified reference values for the target elements (Table 1). These findings confirm the precision and dependability of the analytical methods applied in this research.

Heavy Metals Concentrations (mg/kg) in Different brand Cosmetics Products
Table 2 indicates that, metals concentrations (mg/kg) in Brand A products (foundation, powder, lipstick, and eye pencils) were of the ranges: lead (0.304-0.432), cadmium (0.129-0.601), chromium (0.074-0.189), cobalt (0.048-0.902), nickel (0.033-0.347), and iron (0.021-0.641). Each of the metals displayed significant ($p \leq 0.05$) variation in concentrations between the different products, lead being the only exception (Figure 1). The ranges of metals concentrations (mg/kg) in Brand B products (Table 2) were Pb (0.161-2.79), Cd (0.106-0.209), Cr (0.123-0.543), Co (0.147-0.834), Ni (0.099-0.574), and Fe (0.057-0.545). The difference concentration of each of the metals between the different Brand B products (foundation, powder, lipstick, and eye pencils) was significant (ANOVA, $p \leq 0.05$) (Figure 2). Metals concentrations (mg/kg) in Brand C products (Table 2) were of the ranges: lead (0.066-0.789), cadmium (0.146-0.787), chromium (0.072-0.377), cobalt (0.117-0.764), nickel (0.314-0.704), and iron (0.063-0.245). Each of the metals displayed significant (ANOVA, $p \leq 0.05$) variation in concentrations between the different products (Figure 3). The ranges of metals concentrations (mg/kg) Brand D products (Table 2) were Pb (0.096-0.435), Cd (0.093-0.265), Cr (0.044-0.371), Co (0.370-0.845), Ni (0.078-0.662), and Fe (0.041-0.107). The difference in concentration of each of the metals between the different Brand B products (foundation, powder, lipstick, and eye pencils) was significant (ANOVA, $p \leq 0.05$) (Figure 4).

Table 1: Analyzed and Reference Values (mg/kg) of the Certified Standard Reference materials (IAEA-336 Lichens)

Metals (mg/kg)	Pb	Cd	Ni	Co	Chromium
Analyzed value	4.96	0.122	0.192	0.690	1.071
Reference value	4.3-5.3	0.10-0.133	0.162-0.201	0.554-0.201	0.891-1.123

Heavy metal concentrations in cosmetics products (foundation, powder, lipstick, and eye pencils) across the four brands (Brands A, B, C, and D) under study, were compared against WHO, NAFDAC, Health Canada, and USFDA standards (Table 2). The metals concentrations (mg/kg) in Brand A products fall within acceptable limits for most metals except Ni, which exceeds the WHO limit. Cadmium levels of Brand A eye pencils on the other hand, exceeded the Health Canada limit of 0.5 mg/kg. Used individually, nickel's elevated levels in powder and lipstick increase risks of dermatitis while cadmium in eye pencils pose risks of renal dysfunction and bone demineralization.

Table 2: Heavy metals concentrations in different brands of facial Cosmetics products (mg/kg)

Cosmetics Brand	Cosmetics Products	Lead	Cadmium	Chromium	Cobalt	Nickel	Iron
Brand A	Foundation	0.354-0.356	0.285-0.289	0.163-0.172	0.998-0.902	0.033-0.049	0.057-0.094
	Powder	0.425-0.432	0.207-0.213	0.100-0.103	0.406-0.426	0.277-0.294	0.070-0.103
	Lipstick	0.304-0.307	0.129-0.133	0.074-0.078	0.212-0.218	0.334-0.347	0.021-0.087
	Eye pencil	0.344-0.349	0.592-0.601	0.179-0.189	0.048-0.065	0.103-0.120	0.145-0.641
Brand B	Foundation	0.169-0.176	0.281-0.290	0.252-0.265	0.612-0.633	0.342-0.360	0.064-0.101
	Powder	0.275-0.279	0.182-0.185	0.327-0.333	0.820-0.834	0.253-0.269	0.078-0.114
	Lipstick	0.169-0.170	0.106-0.112	0.123-0.126	0.546-0.563	0.557-0.574	0.057-0.091
	Eye pencil	0.161-0.207	0.116-0.122	0.539-0.543	0.147-0.148	0.099-0.120	0.125-0.545
Brand C	Foundation	0.104-0.109	0.218-0.226	0.316-0.321	0.274-0.292	0.314-0.336	0.074-0.111
	Powder	0.066-0.069	0.334-0.340	0.076-0.082	0.340-0.373	0.686-0.704	0.068-0.105
	Lipstick	0.195-0.197	0.146-0.149	0.072-0.076	0.754-0.764	0.416-0.429	0.063-0.096
	Eye pencil	0.777-0.789	0.779-0.787	0.371-0.377	0.117-0.120	0.612-0.636	0.079-0.245
Brand D	Foundation	0.426-0.435	0.101-0.111	0.365-0.371	0.370-0.391	0.078-0.094	0.041-0.078
	Powder	0.227-0.231	0.256-0.265	0.253-0.258	0.827-0.845	0.634-0.662	0.064-0.099
	Lipstick	0.294-0.297	0.093-0.097	0.138-0.141	0.652-0.665	0.220-0.234	0.066-0.099
	Eye pencil	0.096-0.098	0.245-0.249	0.049-0.054	0.689-0.706	0.351-0.368	0.074-0.107
WHO		10.00	3.00	0.50	4.00	0.20	30.00
NAFDAC/Health Canada		10.00	3.00 (0.5)	1.50	25.00	0.40	40.00
US FDA		10.00-20	3.00	50.00	20.00	200.00	20.00

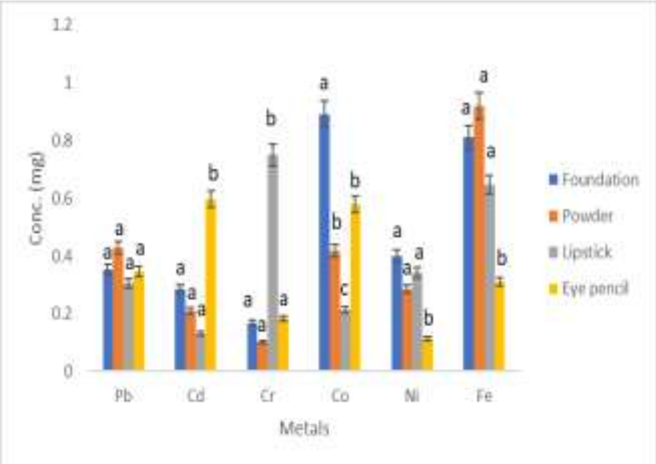

Figure 1: Comparison of metals concentrations in Brand A products **(**foundation, powder, lipstick, and eye pencils)
Bars with different superscripts indicate significant (ANOVA, p ≤ 0.05) difference in metal levels

Prolonged exposure to multiple metals from simultaneous usage of the four Brand A product studied may exacerbate health risks, including neurotoxicity from Pb and renal damage from Cd.[11] The Brand B products had Pb, Cd, Co, and Fe levels within WHO guidelines while nickel concentrations in foundation, powder and lipstick exceeded WHO limits. Chromium contents of Brand B eye pencil also exceeded the WHO limit of 0.5 mg/kg.

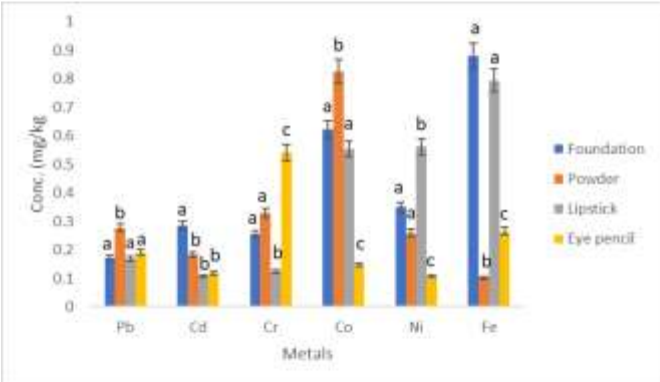

Figure 2: Comparison of metals concentrations in Brand B products **(**foundation, powder, lipstick, and eye pencils)
Bars with different superscripts indicate significant (ANOVA, p ≤ 0.05) difference in metal levels

Based on single product usage, high nickel levels in foundation, powder, and lipstick, and Cr levels eye pencil may lead to dermatitis and allergic reactions. Concurrent exposure through the use of all the

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four products, increases the cumulative systemic exposure dosage, heightening the risk of multi-organ toxicity.[3] Brand C and Brand D products showed Pb, Cd, Co, and Fe concentrations remaining below regulatory standards. However, Ni levels were concerning due to exceedance of WHO limits. Cadmium levels Brand C eye pencils also exceeded the Health Canada limit of 0.5 mg/kg. Daily usage of all the Tarra, or Brand D products, cumulatively increases dermal and systemic exposure, exacerbating health risks from Cd, and Ni, emphasizing the need for stricter quality controls.[6, 3, 11] Comparative studies in facial cosmetics from Nigeria and other regions reveal consistent heavy metal contamination patterns: Pb levels in this study (0.066–2.79 mg/kg) are lower than those reported by Al-Dayel *et al*.,[14] in Middle Eastern cosmetics (5.2–9.3 mg/kg) but align with levels in Nigerian products (0.5–2.1 mg/kg) reported by Iwegbue *et al*.,[19] Cd concentrations (0.106–0.787 mg/kg) are comparable to findings by Hajializadeh *et al*.,[3] in Iranian cosmetics (0.1–0.9 mg/kg). Jeevan & Sharma (2023) reported Cd levels in Nigerian powders ranging from 0.3-0.8 mg/kg and Chouhan *et al*.,[15] identified Cd concentrations of 0.5-1.0 mg/kg in European foundations. Tiwari *et al*.,[9] documented Cr levels in Indian lipsticks at 0.3-0.8 mg/kg and Smith & Johnson, [17] observed Cr levels of 0.2-0.6 mg/kg in American powders. Panahi *et al*.,[6] found Co levels of 0.5-1.2 mg/kg in Middle Eastern foundations and Gao *et al*.,[16] documented Co levels up to 0.7 mg/kg in Asian lipsticks. Jeevan & Sharma,[13] reported Ni levels of 0.3-0.7 mg/kg in Nigerian lipsticks and Chouhan *et al*. (2020)[15] observed Fe concentrations ranging from 15-45 mg/kg in American foundations. These findings align with this study's results, highlighting a global issue in cosmetic safety.[9] Significant differences ($p \leq 0.05$) in metals concentrations between foundation, powder, lipstick, and eye pencils were noted across the four brands (Figure 2-5), lead in Brand A products being the only exception. This observation may indicate, variability in raw materials, contamination sources or formulations.

Systemic exposure dosage (SED) for the different brands of Cosmetics Products

The average Systemic exposure dosage (mg/kg) of lead, cadmium, chromium, cobalt, nickel and iron were: 0.08204, 0.05177, 0.02812, 0.13593, 0.03496, and 0.01821respectively for Brand A products, 0.04702, 0.04881, 0.06109, 0.15153, 0.06533, and 0.01999 for Brand B products, 0.01902, 0.05858, 0.0413, 0.06875, 0.10686, and 0.01999 for Brand C products, and 0.0694, 0.03823, 0.06461, 0.12819, 0.07699, and 0.01611 for Brand D products (Table 3).

Systemic Exposure Dosage (SED) was used to assess the potential health risks of heavy metals (e.g., lead, cadmium, chromium, cobalt, nickel, and iron) present in facial cosmetics.

Table 3: Systemic exposure dosage (SED) for the different brands of facial Cosmetics Products (mg/kg/day)

Cosmetics Brand	Cosmetics Products	Lead	Cadmium	Chromium	Cobalt	Nickel	Iron
Brand A	Foundation	0.14582	0.11768	0.06926	0.36796	0.01651	0.03338
	Powder	0.17636	0.08623	0.04159	0.17181	0.11701	0.03787
	Lipstick	0.00549	0.00234	0.00136	0.00385	0.00617	0.00117
	Eye pencil	0.00048	0.00082	0.00025	0.00008	0.00016	0.00043
	Average	**0.08204**	**0.05177**	**0.02812**	**0.13593**	**0.03496**	**0.01821**
Brand B	Foundation	0.07066	0.11750	0.10554	0.25607	0.14391	0.03624
	Powder	0.11411	0.07563	0.13587	0.33987	0.10710	0.04194
	Lipstick	0.00305	0.00196	0.00223	0.00998	0.01016	0.00143
	Eye pencil	0.00026	0.00016	0.00074	0.0002	0.00015	0.00036
	Average	**0.04702**	**0.04881**	**0.06109**	**0.15153**	**0.06533**	**0.01999**
Brand C	Foundation	0.04369	0.09135	0.13089	0.11609	0.13306	0.04031
	Powder	0.02777	0.13924	0.03247	0.14512	0.28594	0.03787
	Lipstick	0.00353	0.00265	0.00133	0.01364	0.00759	0.00153
	Eye pencil	0.00108	0.00107	0.00051	0.00016	0.00085	0.00026
	Average	**0.01902**	**0.05858**	**0.0413**	**0.06875**	**0.10686**	**0.01999**
Brand D	Foundation	0.17728	0.04364	0.15144	0.15682	0.03491	0.02673
	Powder	0.09486	0.10725	0.10522	0.34315	0.26848	0.03599
	Lipstick	0.00533	0.00169	0.00169	0.01184	0.00407	0.00159
	Eye pencil	0.00013	0.00034	0.00007	0.00095	0.00049	0.00013
	Average	**0.0694**	**0.03823**	**0.06461**	**0.12819**	**0.07699**	**0.01611**
PTDI (mg/kg^{-1}bw day^{-1})		**0.025**	**0.056**	**0.23**	**0.12**	**0.84**	**>45**

Table 3: Systemic exposure dosage (SED) for the different brands of facial Cosmetics Products (mg/kg/day)

Cosmetics Brand	Cosmetics Products	Lead	Cadmium	Chromium	Cobalt	Nickel	Iron
Brand A	Foundation	0.14582	0.11768	0.06926	0.36796	0.01651	0.03338
	Powder	0.17636	0.08623	0.04159	0.17181	0.11701	0.03787
	Lipstick	0.00549	0.00234	0.00136	0.00385	0.00617	0.00117
	Eye pencil	0.00048	0.00082	0.00025	0.00008	0.00016	0.00043
	Average	**0.08204**	**0.05177**	**0.02812**	**0.13593**	**0.03496**	**0.01821**
Brand B	Foundation	0.07066	0.11750	0.10554	0.25607	0.14391	0.03624
	Powder	0.11411	0.07563	0.13587	0.33987	0.10710	0.04194
	Lipstick	0.00305	0.00196	0.00223	0.00998	0.01016	0.00143
	Eye pencil	0.00026	0.00016	0.00074	0.0002	0.00015	0.00036
	Average	**0.04702**	**0.04881**	**0.06109**	**0.15153**	**0.06533**	**0.01999**
Brand C	Foundation	0.04369	0.09135	0.13089	0.11609	0.13306	0.04031
	Powder	0.02777	0.13924	0.03247	0.14512	0.28594	0.03787
	Lipstick	0.00353	0.00265	0.00133	0.01364	0.00759	0.00153
	Eye pencil	0.00108	0.00107	0.00051	0.00016	0.00085	0.00026
	Average	**0.01902**	**0.05858**	**0.0413**	**0.06875**	**0.10686**	**0.01999**
Brand D	Foundation	0.17728	0.04364	0.15144	0.15682	0.03491	0.02673
	Powder	0.09486	0.10725	0.10522	0.34315	0.26848	0.03599
	Lipstick	0.00533	0.00169	0.00169	0.01184	0.00407	0.00159
	Eye pencil	0.00013	0.00034	0.00007	0.00095	0.00049	0.00013
	Average	**0.0694**	**0.03823**	**0.06461**	**0.12819**	**0.07699**	**0.01611**
PTDI (mg/kg^{-1}bw day^{-1})		**0.025**	**0.056**	**0.23**	**0.12**	**0.84**	**>45**

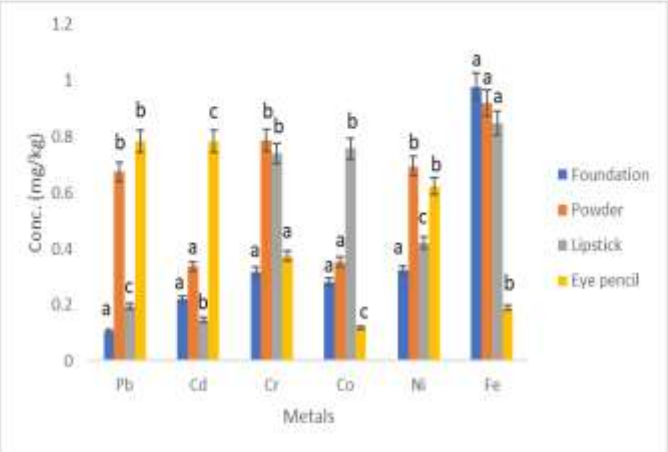

Figure 3: Comparison of metals concentrations in Brand C products **(**foundation, powder, lipstick, and eye pencils)
Bars with different superscripts indicate significant (ANOVA, p ≤ 0.05) difference in metal levels

By calculating the SED for each metal in different products (foundations, powders, lipsticks, and eye pencils), the study quantifies the level of exposure for typical users based on their cosmetic application habits.

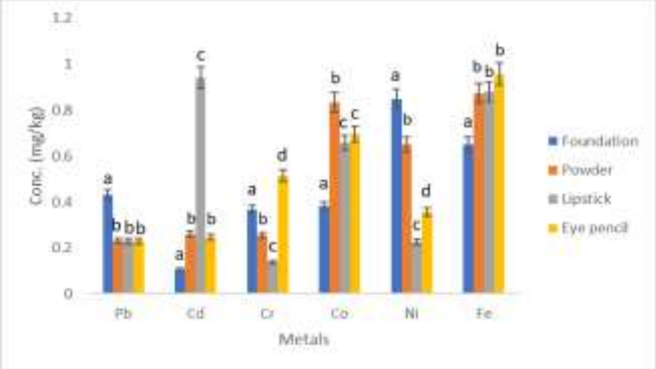

Figure 4: Comparison of metals concentrations in Brand D products **(**foundation, powder, lipstick, and eye pencils)
Bars with different superscripts indicate significant (ANOVA, p ≤ 0.05) difference in metal levels

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Comparing SED values with established safety thresholds (Provisional Tolerable Daily Intake, PTDI) highlights potential health concerns. The study revealed that, the average SED for chromium, nickel and iron cross all brands were below their respective PTDI, consequently all products across brands exhibited safe profile for these metals. On the other hand, lead, cadmium, and cobalt displayed average SED higher than the PTDI across several brand (Table 3). Cobalt posed the highest systemic risk across all brands, particularly in Brand C, Brand A, and Brand D. Among brands, Brand C products exhibited the safest profile for Pb exposure. Lead exposure from Brand A, Brand D, and Zaran products were notably high. Cadmium exposure from Brand A and Brand C were also high, with significant adverse public health implications [11]

Margin of safety (MoS) for the different brands of Cosmetics products (mg/kg)

The average Margin of safety (mg/kg) of lead, cadmium, chromium, cobalt, nickel and iron were: 0.02392, 0.00028, 0.00179, 0.000759, 0.87496, and 11.32826 respectively for Brand A products, 0.04407, 0.00085, 0.000681, 0.002554, 0.02449, and 12.34981 for Brand B products, 0.03831, 0.000167, 0.001082, 0.000358, 0.17809, and 15.92837 for Brand C products, and 0.08291, 0.000588, 0.005586, 0.000575, 0.31305, and 5.121753 for Brand D products (Table 4).

Table 4: Margin of safety (MoS) for the different brands of facial Cosmetics products (mg/kg)

Cosmetics Brand	Cosmetics Products	Lead	Cadmium	Chromium	Cobalt	Nickel	Iron
Brand A	Foundation	0.00029	4×10^{-8}	0.000025	0.000005	0.03271	0.41941
	Powder	0.00024	0.000006	0.000036	0.000011	0.00461	0.36969
	Lipstick	0.00765	0.00021	0.00110	0.00052	0.08752	11.96581
	Eye pencil	0.08750	0.00061	0.00600	0.00250	3.37500	32.55814
	Average	**0.02392**	**0.00028**	**0.00179**	**0.000759**	**0.87496**	**11.32826**
Brand B	Foundation	0.00059	0.000004	0.000014	0.000008	0.00375	0.38631
	Powder	0.00037	0.000007	0.000011	0.000006	0.00504	0.33381
	Lipstick	0.01377	0.00026	0.00067	0.00020	0.05315	9.79021
	Eye pencil	0.16154	0.00313	0.00203	0.01000	0.03600	38.88889
	Average	**0.04407**	**0.00085**	**0.000681**	**0.002554**	**0.02449**	**12.34981**
Brand C	Foundation	0.00096	0.000005	0.000011	0.000017	0.00406	0.34731
	Powder	0.00151	0.000004	0.000046	0.000014	0.00189	0.36969
	Lipstick	0.11189	0.00019	0.00133	0.00015	0.07115	9.15033
	Eye pencil	0.03889	0.00047	0.00294	0.00125	0.63529	53.84615
	Average	**0.03831**	**0.000167**	**0.001082**	**0.000358**	**0.17809**	**15.92837**
Brand D	Foundation	0.00024	1.15×10^{-5}	0.000009	0.000012	0.01547	0.52376
	Powder	0.00044	0.000005	0.000014	0.000006	0.00201	0.38899
	Lipstick	0.00788	0.00029	0.00089	0.00017	0.13268	8.80503
	Eye pencil	0.32308	0.00147	0.02143	0.00211	1.10204	10.76923
	Average	**0.08291**	**0.000588**	**0.005586**	**0.000575**	**0.31305**	**5.121753**
PTDI ($mg/kg^{-1}bw\ day^{-1}$)		**0.025**	**0.056**	**0.23**	**0.12**	**0.84**	**>45**

The Margin of Safety (MoS) is a risk assessment metric that was used to determine how much lower the systemic exposure dosage (SED) of a metal is compared to its threshold for adverse effects. It indicates the safety buffer between the actual exposure to a metal and the level known to cause harm. Higher MoS indicates a larger safety margin and less risk. Lower MoS (<1) on the other hand indicates higher risk, as the exposure approaches or exceeds levels associated with adverse effects.

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Hazard quotient (HQ) and hazard index (HI) for the different brands of Cosmetics products

The average Hazard quotient (mg/kg) of lead, cadmium, chromium, cobalt, nickel and iron were: 0.195325, 10.3535, 1.874335, 7.10775, 0.006475, and 0.00013 respectively for Brand A products, 0.113953, 9.7625, 4.073, 7.5765, 0.012098, and 0.000141 respectively, for Brand B products, 0.045278, 11.7155, 2.753335, 3.437625, 0.019788, and 0.000143 respectively, for Brand C products, and 0.165238, 7.646, 4.307003, 6.4095, 0.014255, and 0.00014 respectively, for Brand D products. The average hazard index for each brand of cosmetics was; 19.53753, 21.53819, 17.96998, and 18.5426 for Brand A, B, C and D respectively (Table 5).

Table 5: Hazard quotient (HQ) and hazard index (HI) for the different brands of facial Cosmetics products (mg/kg)

Cosmetics Brand	Cosmetics Products	HQPb	HQCd	HQCr	HQCo	HQNi	HQFe	HI
Brand A	Foundation	0.34719	23.536	4.61733	18.398	0.00306	0.00024	46.9019
	Powder	0.41990	17.246	2.77267	8.5905	0.02167	0.00027	29.05101
	Lipstick	0.01307	0.468	0.09067	0.1925	0.00114	0.000008	0.76539
	Eye pencil	0.00114	0.164	0.01667	1.25	0.00003	0.000003	1.43184
	Average	0.19533	10.3535	1.874335	7.10775	0.006475	0.00013	19.53753
Brand B	Foundation	0.16824	23.5	7.036	12.8035	0.02665	0.00026	43.53434
	Powder	0.27969	15.126	9.058	16.9935	0.01983	0.00029	41.46972
	Lipstick	0.00726	0.392	0.14867	0.499	0.00188	0.00001	1.04882
	Eye pencil	0.00062	0.032	0.04933	0.01	0.00003	0.000003	0.09198
	Average	0.113953	9.7625	4.073	7.5765	0.012098	0.000141	21.53819
Brand C	Foundation	0.10402	18.27	8.726	5.8045	0.02464	0.00029	32.929
	Powder	0.06612	27.848	2.16467	7.256	0.05295	0.00027	37.3817
	Lipstick	0.00840	0.53	0.08867	0.682	0.0014	0.00001	1.31048
	Eye pencil	0.00257	0.214	0.034	0.008	0.00016	0.000002	0.25873
	Average	0.045278	11.7155	2.753335	3.437625	0.019788	0.000143	17.96998
Brand D	Foundation	0.42209	8.728	10.096	7.841	0.00646	0.00019	27.0935
	Powder	0.22586	21.45	7.01467	17.1575	0.04972	0.00026	45.8972
	Lipstick	0.01269	0.338	0.11267	0.592	0.00075	0.00011	1.05912
	Eye pencil	0.00031	0.068	0.00467	0.0475	0.00009	0.000001	0.12058
	Average	0.165238	7.646	4.307003	6.4095	0.014255	0.00014	18.5426

Hazard quotients and hazard index are valuable tools used to assess health risk in this study. Hazard quotient values revealed that, the risk posed by lead, nickel and iron across brands are negligible or not significant, whereas, cadmium, chromium and cobalt pose significant non carcinogenic risk across brand (Table 5). It indicated Cadmium as the most hazardous metal in all brands, with the highest HI observed in Brand B products. Average Hazard index across brand indicates significant non carcinogenic risks, underscoring the need for targeted risk management strategies.[21]

Lifetime cancer risk (LCR) and Cumulative cancer risk (CCR) from the different brands of Cosmetics products

The average Lifetime cancer risk (mg/kg) of lead, cadmium, chromium, and nickel were: 0.00075, 0.32909, 0.02585, and 0.02956 respectively for Brand A products, 0.00053, 0.32704, 0.03056, and 0.05945 respectively, for Brand B products, 0.00021, 0.39247, 0.02066, and 0.09724 respectively, for Brand C products, and 0.00079, 0.25614, 0.03231, and 0.06998 respectively, for Brand D products (Table 6). The average value of the Cumulative cancer risk for each brand of cosmetics was; 0.38506, 0.41746, 0.51053, and 0.35902 for Brands A, B, C and D respectively (Table 6). The risk level for carcinogens deemed acceptable varies from 10^{-4}, where the lifetime cancer risk is 1 in 10,000, to 10^{-6}, where the lifetime cancer risk is 1 in 1,000,000.[26] Risks below 10^{-6} are considered negligible, while those above 10^{-4} are deemed unacceptable. The lifetime cancer risk values revealed cadmium, nickel, chromium pose significant carcinogenic risk. Cadmium posed the highest carcinogenic risk, particularly in Brand C products (0.39247 mg/kg). Brand C products also showed the highest CCR (0.51053), driven by cadmium and nickel exposure. The findings suggest long-term carcinogenic risks from multi-product use, underscoring public health concern.[25]

Table 6: Lifetime cancer risk (LCR) and Cumulative cancer risk (CCR) from the different brands of facial Cosmetics products (mg/kg)

Cosmetics Brand	Cosmetics Products	Lead	Cadmium	Chromium	Nickel	CCR
Brand A	Foundation	0.00124	0.78846	0.03463	0.01502	0.83935
	Powder	0.00097	0.50672	0.06794	0.09746	0.67309
	Lipstick	0.00005	0.01568	0.00068	0.00561	0.02202
	Eye pencil	4×10^{-6}	0.00549	0.00013	0.00015	0.00577
	Average	**0.00075**	**0.32909**	**0.02585**	**0.02956**	**0.38506**
Brand B	Foundation	0.0006	0.78725	0.05277	0.13096	0.97158
	Powder	0.00097	0.50672	0.06794	0.09746	0.67309
	Lipstick	0.00003	0.01313	0.00116	0.00925	0.02357
	Eye pencil	2×10^{-6}	0.00107	0.00037	0.00014	0.00158
	Average	**0.00053**	**0.32704**	**0.03056**	**0.05945**	**0.41746**
Brand C	Foundation	0.00037	0.61205	0.06545	0.12108	0.79895
	Powder	0.00024	0.93291	0.01624	0.26021	1.20959
	Lipstick	0.00003	0.01776	0.00067	0.00691	0.02537
	Eye pencil	9×10^{-6}	0.00717	0.00026	0.00077	0.00821
	Average	**0.00021**	**0.39247**	**0.02066**	**0.09724**	**0.51053**
Brand D	Foundation	0.00151	0.29239	0.07572	0.03177	0.40139
	Powder	0.00081	0.71858	0.05261	0.24432	1.01632
	Lipstick	0.00005	0.01132	0.00085	0.0037	0.01592
	Eye pencil	1×10^{-6}	0.00228	0.00004	0.00012	0.00244
	Average	**0.00079**	**0.25614**	**0.03231**	**0.06998**	**0.35902**

Conclusion

The study confirms the presence of hazardous heavy metals in widely used facial cosmetics in Calabar. Significant variations in heavy metal contamination across cosmetic brands and between products were observed. Key contaminants such as nickel, cadmium, lead, and chromium were found at levels exceeding recommended safety thresholds. The presence of nickel in lipsticks and powders raises concerns regarding allergic dermatitis, while high cadmium levels in eye pencils pose risks of renal dysfunction and bone demineralization. Prolonged exposure through daily cosmetic use increases the likelihood of systemic toxicity, particularly from cadmium and Cobalt. The presence of carcinogenic and non-carcinogenic heavy metals raises concerns over cumulative exposure risks, necessitating urgent regulatory interventions. Comparative analysis with similar studies worldwide suggests that heavy metal contamination in facial cosmetics is a global issue. The findings underscore the urgent need for stricter cosmetic safety regulations to protect consumers from long-term exposure to toxic heavy metals. Investigations into alternative cosmetic formulations that minimize heavy metal contamination is strongly recommended. Expanding research to include other commonly used personal care products and their toxicological impact is also recommended

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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